AGRICULTURAL METEOROLOGY

Instructional-cum-Practical Manual

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राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country by providing education for better employability of the youth.

In view of the importance of the programme the NCERT is making an all out effort to provide academic support to the implementing agencies in the States. One of the major contributions of NCERT is in the field of curriculum development and in the development of model instructional materials. The materials are developed through workshops in which experts, subject specialists, employers' representatives, curriculum framers and teachers of the vocational course are involved. These materials are then sent for try-out in schools and feedback is collected through questionnaires and through direct contact. The materials are also sent to experts for comment before they are published.

The present manual on **Agricultural Meteorology** has been developed in the manner described above and is meant for the students studying Crop Production and allied vocations. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the manual useful.

I am grateful to all those who have contributed to the development of this manual. I must acknowledge also the immense interest taken by Prof. A.K. Mishra, Head, Department of Vocationalization of Education in inspiring his colleagues in their endeavours to develop instructional materials. Dr. A.K. Sacheti, Reader, functioned as the Project Coordinator for the development of this title in association with Dr. A.K. Dhote, Lecturer. They have my appreciation and thanks for planning, designing and conducting

the workshops, for technical editing and for seeing this manual through the Press.

Suggestions for improvement of this manual will be welcome.

P. L. MALHOTRA
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New Delhi
October, 1985

PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories in our country the paucity of appropriate instructional materials has been felt as one of the major constraints in implementation of the programme and a source of great hardship of pupils offering vocational studies at the higher secondary stage.

The Department of Vocationalization of Education of the National Council of Educational Research and Training, New Delhi has started a modest programme of developing instructional materials of diverse types to fill-up this void in all major areas of vocational education. The task is too gigantic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a Working Group of experts constituted by NCERT.

The present manual is on **Agricultural Meteorology** and is meant for the pupils and the teachers teaching Crop Production and allied Vocations being offered in a number of States. It contains activities (Practical exercises) to be performed by pupils with simple steps to follow, precautions to be taken and data to be obtained and processed. Each activity is complete with objectives, relevant information, behavioural outcomes, evaluation, etc. It is hoped that the users will find them immensely useful.

The experimental edition of the manual was developed by a group of experts as contributors in a workshop held at the Andhra Pradesh Agricultural University (APAU), Rajendranagar, Hyderabad, Andhra Pradesh. The same was later circulated to receive the feedback from the user pupils and teachers in the States of Tamil Nadu, Andhra Pradesh and Maharashtra. After a period of one year for the try-out, the feedback was received and accordingly the experimental edition was suitably reviewed and revised through a committee of experts in a workshop held at the University of Agricultural Sciences, Hebbal, Bangalore. The names of the

contributors and reviewers are mentioned elsewhere and their contributions are admirably acknowledged. We are grateful to all the institutions, students and teachers who have used the manual and sent their comments. Our thanks are also due to Srhi T. Madan Mohan Reddy, Asstt. Professor, Department of Agronomy, College of Agriculture, APAU, Hyderabad, Andhra Pradesh for the pains he took in varyfying the authenticity of the contents of the experimental edition of the manual. Dr. A.K. Sacheti, Reader and Co-ordinator of this Project and Dr. A.K. Dhote, Lecturer, Department of Vocationalization of Education deserve special thanks for editing and bringing the manual in the present form. The assistance of all in the APAU Rajender Nagar, Hyderabad, Andhra Pradesh; the University of Agricultural Sciences, Hebbal, Bangalore and the Deparment of Vocationalization of Education, NCERT is also thankfully acknowledged.

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Contributors

Dr. A. Krishnan, Dr. C.V.S. Sastri, Dr. R. Kulandaivelu, Dr. A.K. Dhote and Dr. A.K. Sacheti.

Reviewers

Dr. A. Krishnan, Dr. E.V. Murali Mohan Rao and Sh. T. Srinivasan

Meteorology is one of them. This manual is intended to help both teachers and pupils in the study of weather parameters and their relationship with production of crops as preparation for this vocation. While developing the manual, care was taken that it should include the maximum number of Activity Units (practical exercises) so that it can fulfil the requirements of the course prescribed by the States and Union Territories in the Crop Production as well as in other vocational courses.

These Activity Units are essential to develop the required vocational skills in the pupils. The manual explains in detail the 'what', 'why', and 'how' of these Units.

In the manual each Activity Unit has been dealt with under several sub-heads, *viz.*, instructional objectives, relevant information, precautions, materials required, procedure, observations, expected behavioural outcomes and questions.

Before commencing the actual work under any Activity Unit, the teacher should know what exactly the pupils have to learn and do, and should also assess whether they will be able to do that. Therefore, in the beginning, instructional objectives for the pupils should be framed in behavioural terms by the teacher.

In order to acquaint the pupils with the Activity Unit the teacher should provide them with the required theoretical knowledge or information relevant to the activity. This will help the pupils to properly understand the Activity Unit. In other words, the 'what' and 'why' parts of the Activity Unit should be explained in advance by the teacher.

Once the pupils have understood the relevant theoretical instructions, the teacher should tell them about the precautions which are to be taken before and during the actual execution of the Activity Unit. This will facilitate smooth working. The 'how' part of the Activity should be explained by the teacher in the 'procedure' which pupil should follow while performing the Activity Unit.

Under the sub-head 'observations', the teacher should tell what to observe and in view of that the pupil should observe the situation, take readings, note down the temperature and similar other points, under each Unit; these may vary from Unit to Unit. Wherever calculations are required to be done to obtain the results, this should also be indicated under this head or under separate head.

At the end of the Activity the pupil will have acquired certain abilities which should be closely related with the instructional objectives formulated for each Activity Unit. These abilities should

be listed under the sub-head 'expected behavioural outcomes'. Evaluation should be based on the abilities acquired and it should be done by the teacher concerned.

For evaluating each aspect, the teacher will use a four-point scale, i.e., A, B, C & D, and for each Activity Unit the Grade Point Average can be calculated as indicated below :

Suppose there are four aspects, each carrying equal weightage, and a pupil obtains 2A's, 1 C and 1 D and if A = 4 point, B=3, C=2 and D=1 point; then, based on the grades, the pupil will get 11 points. When the number of points obtained is divided by the total number of aspects examined, it will give the Grade Point Average, which, in this case, is 2.75. The tabular presentation is as under :

Aspects	*Weightage*	*Grades Obtained*	*TOTAL POINTS (weightage × point-equivalent to grade obtained)*	*Grade Point Average*
1	1	A	1 × 4 = 4	
2	1	C	1 × 2 = 2	= 11/4 = 2.75
3	1	D	1 × 1 = 1	
4	1	A	1 × 4 = 4	
			11	

At the end of the Activity Unit, some questions relevant to it are also given. The pupils should write the appropriate answers after the completion of the Activity Unit and teacher should examine them. If required, he should make suitable corrections and give suggestions. However, answers to these questions will not be considered for the purpose of grading.

CONTENTS

INTRODUCTION

Agriculture is the main occupation of the people of India with nearly 75 per cent of the country's working population engaged in it. Almost 50 per cent of the Gross National Product (GNP) is accounted for by agricultural production. Agriculture not only supplies raw materials for a number of important industries but also provides products which form major share of country's foreign exchange earnings. However, even today agriculture in India is largely dependent on prevailing weather conditions especially the rainfall, as hardly 25 per cent of the cropped area is having assured and adequate supply of irrigation water. In India, the Kharif crop raised during the South-West monsoon period are exposed to slight or severe water stress in different regions of India depending on the deficient rainfall spells associated with "breaks" in monsoon and severe floods occurring due to the erratic movement of the monsoon depressions. The Rabi crops grown without irrigation depend on the soil moisture accumulated during the preceding monsoon since the winter rainfall is meagre in different regions of India and its distribution is erratic. The occurrence of droughts due to large year to year fluctuations of total annual rainfall and deficient rainfall spells within the crop growing season is a major determining factor of agriculture in India inspite of phenomenal technological advancements made by way of introduction of improved varieties, higher fertilizer use and better plant protection and water management practices etc. During drought periods, prevalence of high temperatures and high wind speeds and evaporation worsen the situation by causing faster depletion of meagre available soil moisture. In view of the above factors, knowledge of the inter-relationship of crop growth and productivity with various meteorological factors becomes extremely important.

So, in this manual, pupils are taught to measure the important meteorological elements which have significant influence on Crop Production. As is well known, the essential requisites for successful raising of crops are water, air, sunlight and soil.

As already stated, rainfall is by far the most important factor in determining final agricultural yields. In hilly regions in the north,

snowfall instead of rainfall occurs due to prevalence of colder temperatures. During the hot weather periods of March to May, violent thunderstorms accompanied by hail occur causing heavy damage to agricultural and horticultural crops. So in Activity Unit-1, the measurement of rain, snow and hail has been discussed. In arid and semi-arid regions,dew forms a valuable supplementary moisture resources for vegetation. Hence the same is discussed in Activity Unit-7.

Air temperature and soil temperature play a vital role in crop growth and development. Crop water use is increased with increase in temperature and there are cardinal temperature (viz. Maximum, Minimum and optimum temperature ranges) for germination and other crop development processes. Final grain yields are also determined by the temperature ranges prevalent during the crop growing season. So, the determination of air temperatures at different hours of the day as well as maximum and minimum values for the day is important and is discussed in Activity Unit-2. Optimum soil temperature is an important condition for proper germination and the soil moisture movement is also dependent on the temperature of the soil. So this aspect is discussed in Activity Unit-8.

Humidity plays an important role in the infestation of crops by pests and diseases and in determination of crop water use. Drier the air, more will be the water losses from crop fields and less is the incidence of pests and diseases. Hence, humidity measurement is discussed in detail in Activity Unit-3.

Solar radiation is one of the most important factors in photosynthesis and transpiration of crops. But since its measurement involves advanced instruments which are available only for a few locations, indirect estimation of the same from sunshine or cloud data would be useful. Hence, the measurement of sunshine and cloud amount has been given under Activity Unit-5. The wind which has also a major role in determining crop water use is discussed in Activity Unit-4.

As already mentioned, dryland farming areas form the majority of the cropped areas in India. Hence study of evaporation and evapotranspiration becomes extremely important. This aspect is discussed in Activity Unit-6 and Activity Unit-9, respectively.

1. Activity Unit

MEASUREMENT OF PRECIPITATION

1.1 Instructional objectives :

The pupil should be able to:

— recall the different forms of precipitation;

— recall the different parts of rain gauge and their functions;

— recall the exposure requirements and installation of rain gauges;

— measure rain, snow and hail;

— compute rainfall intensity of a given rain spell;

— calculate the quanity of water received by crop fields from rainfall spells of specified amount.

1.2 Relevant information :

— What is precipitation?

Precipitation is defined as particles of liquid water or ice formed within a cloud and falling towards the ground. There are atleast three main forms of precipitation viz., rain, snow and hail. Rain is the liquid form of precipitation while snow consists of ice crystals, generally in flakes of light feathery structure. Hail usually falls during severe thunder storms due to violent convection and consists of ice balls or lumps of bigger sizes. In a thunder cloud, strong vertical air currents carry the rain drops above and below the freezing level resulting in the growth of hail by alternate accumulation of snow and water..Thus, these ice balls are called hail stones and they fall to the ground during hail storm.

— What are the different parts of a raingauge?

The essential parts of a raingauge are: (a) funnel which has a brass rim of diameter 127 mm, (b) cylindrical body, (c) receiver with a narrow neck and handle, (d) splayed base which is fixed in the ground and (d) measuring cylinder (Fig. 1.2.1).

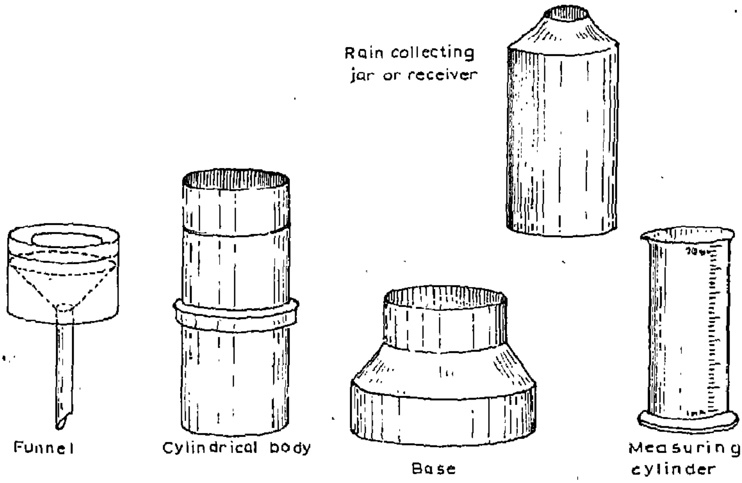

Fig. 1.2.1 DIFFERENT PARTS OF A RAIN GAUGE

—What are the exposure requirements of the installation of a raingauge?

A raingauge should be installed on a level ground, not upon a slope or terrace and never on a wall or roof. It should not be installed on a ground that has slope on the side of the prevailing wind since in that case quite a few rain drops will be carried away by winds. In order to avoid loss of rain drops due to obstruction, the distance of any object should be atleast twice the height of the object above the rim of the raingauge.

—How is the raingauge installed?

The raingauge should befixed on a masonry or a concrete foundation of 60 cm x 60 cm x 60 cm sunk into the ground. The base of the gauge is cemented into this foundation so that the rim of the gauge is exactly 30 cm above ground level. This height is chosen in order to minimise water splashing into the gauge. If the height of the rim is more, the rain water collected would decrease because of the change in wind structure near the gauge. The top of the rim of the raingauge should be perfectly level.

— How is rainfall measured?

The rain falling into the funnel of the raingauge is collected in the

receiver kept inside the body and is measured by means of a special measuring glass cylinder graduated in millimetres. Ten millimetres of rain means that if that rainfall is allowed to be collected on a flat surface, the height of the water collected would be 10 mm. In case the above mentioned special measuring glass cylinder is not available, rain water can be measured by commonly available measuring glass graduated in ml. In such cases, 126.7 ml water measured is equal to 10 mm rain. This conversion is, however, applicable to the raingauge of 127 rim diameter.

—How are snow fall and hail measured?

Snowfall is measured by means of special snow gauges. These gauges are of 127 mm or 200 mm rim diameter and are mounted on iron stands at a height above the average snow level of the location. A known quantity of warm water is poured into the receiver in which snowfall has been collected. After melting of the snow, the total amount of water is measured. The actual amount of snowfall is obtained by subtracting from this, the amount of warm water added. During hail also, water and hail stones collected in the receiver are measured in a similar manner.

—What is intensity of a rainfall spell and how it is measured?

The intensity of a rainfall spell is defined as the ratio of the total amount of rainfall recorded during the spell to the total duration of the spell. It is expressed in mm per hour. For recording the total amount of rainfall in a particular rainfall spell, a special self recording raingauge is used. It consists of a float chamber containing a light hollow float. As the water collected by the outer funnel is led into this chamber, the float rises along with the water level and the vertical movement of the float is recorded by a pen on a chart fixed on a rotating clock drum. This chart has a range of 10 mm. As soon as 10 mm of rain falls, the pen reaches the top line of the chart. But the instrument has a syphoning arrangement. So, the water in the chamber gets emptied and the pen and float come to the initial position immediately. If there is further rain, the pen continues to rise and record the rainfall in the above manner. Thus, if in a particular rainfall spell there are two syphonings followed by the rise of pen to 5 mm, the total amount of rain received during the spell is 25 mm. If the duration of this spell is 30 minutes, as seen from the chart, then the intensity of the rain fall spell is 25/30 x 60 or 50 mm/hour.

In this way, intensity of a particular rainfall spell can be calculated.

—How is the quantity of water received in a crop field from a particular rainfall amount determined?

As explained earlier, the rainfall is measured in depth units viz. mm. So, if the area of the crop field (A) in sq. cm and the rainfall amount (R) in cm are known, the volume of water (V) in cu.cm. received over the crop field can be calculated by the following formula.

$V = A \times R$

Since 1000 cubic centimetres is 1 litre and 1000 litres is 1 kilo litre, we can calculate the volume of water in litres or in kilo litres.

For example, if the area of the crop field is 0.6 hectare and rainfall recorded is 24 mm, the volume of rain water received in that crop field can be calculated as follows:

$$\begin{aligned} V &= 0.6 \times 10{,}000 \times 10{,}000 \times 2.4 \text{ cu.cm.} \\ &= 144{,}000{,}000 \text{ cu.cm} \\ &= 144{,}000 \text{ litres} \\ &= 144 \text{ kilo litres} \end{aligned}$$

1.3 Precautions :

- Avoid spilling of the rain water while transferring from raingauge receiver to the measuring cylinder.
- Avoid parallax error while reading the level of water in the measuring cylinder. For this, the observer should keep his eye at the level of water in the cylinder while measuring.
- Use appropriate measuring glass cylinder provided with the raingauge.
- If during heavy rainfall, water in the receiver has over flown and fallen into the outer cylinder, the quantity of water collected in the receiver as well as in the outer cylinder should be added.
- Alternatively, on days of heavy rainfall, more frequent measurements should be made in order to avoid overflow and all these amounts should be added up.

1.4 Materials required :

i. Ordinary raingauge installed as per standard procedure.
ii. Measuring cylinder appropriate to the raingauge.
iii. Basin

1.5 Procedure :

— Remove the funnel of the raingauge.
— Take out the receiver containing rainwater collected.
— Place the measuring cylinder in a basin and transfer the content of the receiver into measuring cylinder.
— Keep back the receiver and funnel in position after the transfer of rain water.
— Hold the measuring cylinder in an upright position or keep it on a table or a horizontal surface.
— Read the water level in the measuring cylinder correct to 0.1 mm (since the water level would be slightly concave due to surface tension, the level of the lower meniscus should be read, avoiding parallax error).

1.6 Observations :

The pupil should take the following observations:

i. Rainfall in mm for 24 hours ending at 0830 hrs. I.S.T.
ii. Rainfall during a particular period of time.

1.7 Expected behavioural outcomes :

The pupil will be able to:

	Grade
— identify different forms of precipitation; — explain the different parts of the raingauge and their functions; — install the raingauge; — measure rainfall; — compute rainfall intensity of a particular rainfall spell; — compute the quantity of water received by the crop fields of different dimensions from the rainfall of specified amounts.	

The teacher should evaluate the pupil for the above abilities.

1.8 Questions :

i. What is the difference between snowfall and hail?

ii. Why does hail occur during summer?

iii. If there is a tree of 10 metres height and a rain gauge is to be installed in its vicinity, what precaution should be taken during the raingauge installation?

iv. How do you measure a rainfall of 45 mm when you are provided with only a 10 mm measuring cylinder?

v. Calculate the intensity of rainfall for the following rainfall spells:

Date	Time of occurrence	Amount (mm)
18.7.1982	0845 - 0915 hrs IST	10.2
	1510 - 1640 hrs IST	15.0

vi. What is the quantity of water received in kilo litres by a cropping land of 0.5 hectare from a rainfall spell of 15 mm?

vii. Snow occurs during winter in the Himalayas while hail occurs during summer even in the plain stations in India. Why?

2. Activity Unit

MEASUREMENT OF AIR TEMPERATURE

2.1 Instructional objectives :

The pupil should be able to :

— explain the meaning of air temperature means, its diurnal variation and how the heat transfer processes are connected with temperature changes;

— measure air temperature including the maximum and minimum values recorded during the day.

2.2 Relevant information :

—*What is air temperature?*

Air temperature is the temperature of the air recorded by the thermometer exposed in a standard type of screen called Stevenson screen (Fig.2.2.1).

— *What is Stevenson screen and what are its functions?*

The object of the screen is to shield the thermometers from radiation from the sun, ground and neighbouring objects, and from losing heat by radiation at night. The screen also protects the thermometer from precipitation while at the same time allowing free circulation of air. It is usually made of teak or a similar wood in the shape of a box with louvered sides and the bottom and double roof having 2-3 inches air space. The shelter is painted white and is usually mounted on an open wooden support, the floor of the screen being at 4 ft. (1.22 m) above the ground. The shelter is set up with its door facing north side so that only minimum sunlight would enter while the observer is reading the instruments.

—*What is the difference between heat and temperature?*

Temperature is the measure of mean kinetic energy per molecule of the molecules in an object, while the heat is the measure of total kinetic energy of all the molecules of that object. A large object may

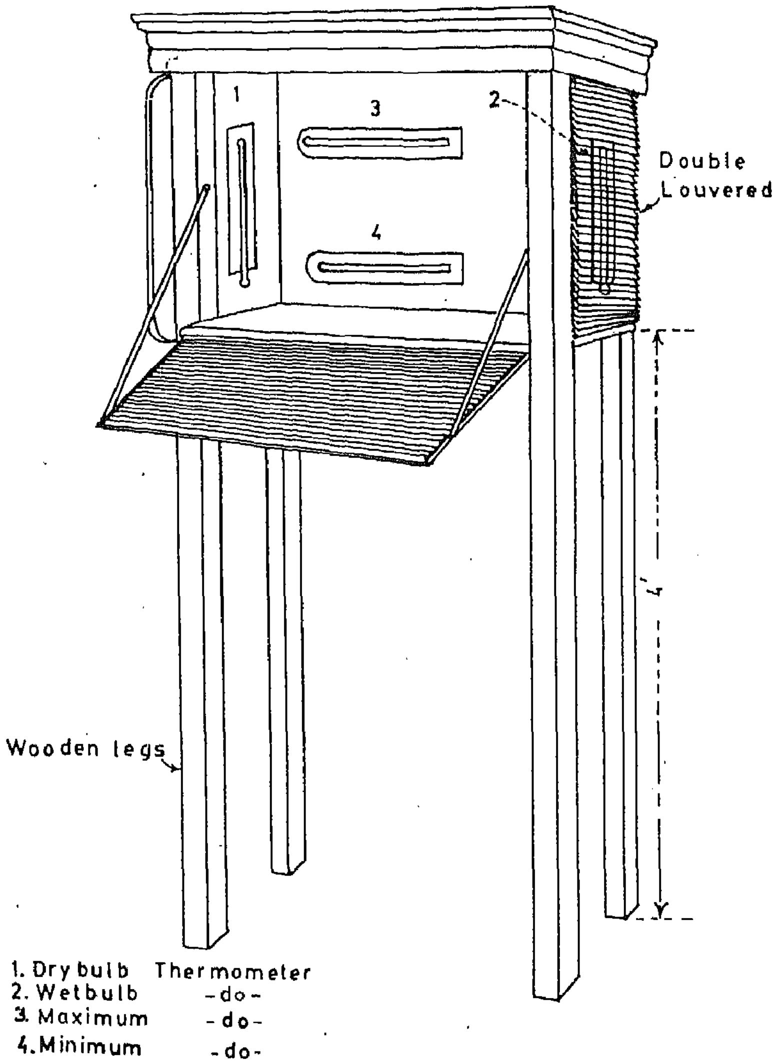

Fig. 2.2.1 STEVENSON SCREEN

have a much lower temperature than a small object and may still have a greater heat content by virtue of larger number of molecules in it. If same quantities of copper and water at the same initial temperatures

are heated by 2 identical burners, the same amount of heat is transferred to both the materials. But the temperatures obtained by them are different. Copper will be at a much higher temperature than water and if after removing the burners, they are placed in contact with each other, heat will flow from copper to water. Thus, heat and temperature are not the same.

—How does heat transfer take place between two bodies having different temperatures?

When two bodies at different temperatures are placed near each other, heat transfer takes place from the hotter body to cooler body in three different ways viz., conduction , convection and radiation.

In the process of conduction, heat is transmitted through a medium by contact of the minute particles in the medium. In convection, the transmission is effected by the actual motion of the heated materials. In radiation, heat flows in the form of electromagnetic waves even if the two bodies are quite apart.

—How does air temperature vary during day and night?

The temperature variations in the air are primarily governed by solar radiation. But the solar radiation is first received by earth's surface and energy is then transferred to the air. On account of the same, although the maximum solar radiation is reached at the noon, the maximum of air temperatue is recorded later, generally between 2 and 3 PM. Thereafter, air temperature decreases during night due to the absence of solar radiation and minimum temperature is reached just before the sunrise.

— How is air temperature measured?

Air temperature is measured by means of a mercury-in-glass thermometer called the dry bulb thermometer which gives the instantaneous reading of the air temperature. For this purpose, this thermometer is installed in a Stevenson screen as indicated earlier. Temperature should be read in degrees centigrade, correct to one point of decimal. The dry bulb thermometer is mounted vertically inside the Stevenson screen.

— How is maximum temperature measured?

The maximum temperature is measured by means of maximum thermometer (Fig. 2.2.2). This is a mercury-in-glass thermometer provided with a constriction in the capillary of the glass tube below

the lowest graduation of the scale. This constriction allows mercury to be forced through with rising temperatures but preve being drawn back with falling temperatures, provided thermometer is kept at an angle of less than 10° from the horizo with the bulb downwards. As the temperature rises, mercury is fo hrough the constriction and stands at that level in the capillary. S are able to read even at a later time the maximum tempera attained during that time interval. The thermometer is mou horizontally in the upper portion of the Stevenson screen. A reading has been taken, maximum thermometer is set by removi from the support, holding it firmly in hand by the remote end f the bulb and swinging it briskly downwards. The reading of maximum thermometer after setting should agree with that of bulb thermometer within 0.3° C

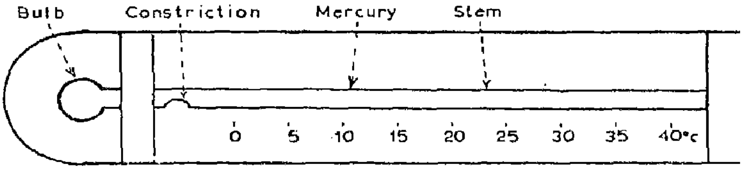

Fig. 2.2.2 MAXIMUM THERMOMETER

-- *How is minimum temperature measured?*

The minimum thermometer (Fig. 2.2.3) has spirit as temperat measuring fluid and is provided with a small dumb bell shaped in in the stem. This index is kept inside the spirit column by the surf tension of the meniscus. As the temperature of the air falls, meniscus retreats towards the bulb dragging with it the index, till minimum temperature is reached. As the temperature rises, the in remains stationary. Thus; the end of the index farthest from the b indicates the minimum temperature recorded since the thermom was last set. To set the minimum thermometer, the bulb end is ti upwards and this is sufficient to cause the index move slowly d

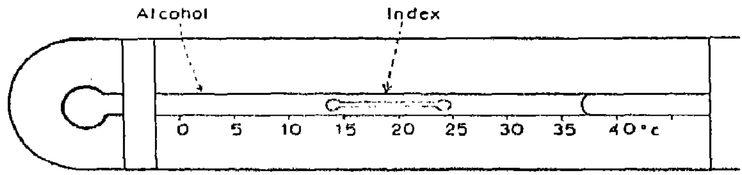

Fig. 2.2.3 MINIMUM THERMOMETER

the tube upto the meniscus. After setting, the reading of the minimum thermometer should be within 0.6° C of the dry bulb temperature. This is installed in a horizontal position in the lower part of the Stevenson screen with an inclination of 5° from the horizontal towards the bulb.

— *What are the mean air temperature and range of temperature for a day?*

The average of the maximum and minimum temperatures recorded during a day is called the mean temperature of the day. The difference between the maximum and the minimum temperatures recorded during a day gives the range of temperature for the day. For example, if maximum and minimum temperatures for a day are 36.5° and 21.3° respectively, the mean temperature for the day is (36.5+21.3)/2 = 28.9°C. Range of temperature of the day is 36.5-21.3 = 15.2°C.

2.3 Precautions :

- Take the temperature reading as quickly as possible, so that it is not affected by your presence.
- After taking temperature readings, index corrections of the thermometers, obtained by calibration done with the standard thermometers earlier, should be applied.
- Avoid parallax error while reading the thermometers.
- After reading the thermometer, verify once again whether the whole number of degrees has been read correctly.
- Do not keep the door of the Stevenson screen open for a longer time than is necessary.

2.4 Materials required :

i. Stevenson screen
ii. Dry bulb thermometer.
iii. Maximum thermometer
iv. Minimum thermometer

2.5 Procedure :

- Open the Stevenson screen.
- Note the reading of the dry bulb thermometer, correct to 0.1°C.
- Note reading of the maximum thermometer correct to 0.1° C.
- Set the maximum thermometer during morning observations (0700 hrs local mean time) and record the set reading.

- Note the reading of minimum thermometer corresponding to the end of the index away from the bulb.
- Set the minimum thermometer during evening observations (1400 hrs local mean time) and record the set reading.

2.6 Observations :

The pupil should take and record the following observations as per the table given below :

Date	*Time (IST)*	*Temperature*			*Test reading at the time of setting*		
		Dry bulb (°C)	*Maxi-mum* (°C)	*Mini-mum* (°C)	*Dry bulb* (°C)	*Maxi-mum* (°C)	*Mini-mum* (°C)

2.7 Expected behavioural outcomes :

The pupil will be able to:

Grade

- explain the air temperature and its diurnal variation;
- explain the heat transfer processes occurring due to temperature changes;
- measure dry bulb temperature, maximum temperature and minimum temperature; and
- set the maximum and minimum thermometers..

The teacher should evaluate the pupil for the above abilities.

2.8 Questions :

i. What are the three processes of heat transfer?

ii. What is the difference between temperature and heat? Illustrate.

iii. Calculate the mean temperature and range of temperature for the following data:

—	Maximum Temperature	Minimum Temperature
a)	41.3°C	24.5°C
b)	27.4°C	21.5°C

iv. Why does the maximum of air temperature lags behind the radiation maximum?

3. Activity Unit

MEASUREMENT OF HUMIDITY

3.1 Instructional objectives :

The pupil should be able to:

- — recall the different measures of humidity;
- — calculate dew point and relative humidity from wet and dry bulb temperature readings;
- — compute vapour pressure and saturation vapour pressure deficit;
- — explain the different forms of atmospheric condensation such as mist and fog;
- — measure wet bulb temperature.

3.2 Relevant information :

— *What are the different measures of humidity?*

The important measures of humidity are vapour pressure, relative humidity and dew point temperature. The air contains about 78% of Nitrogen, 20% of Oxygen and many other gases including water vapour in small proportions. The pressure of air is the total weight of all the gases on unit area. Since water vapour also contributes to this air pressure, the partial pressure due to water vapour alone is called '*vapour pressure*'. It is expressed in energy units viz. millibars or millimetres of mercury.

When air is in contact with water, water evaporates into air as water vapour. As more and more water is evaporated, amount of water vapour in air increases. However, at any particular temperature, there is a maximum capacity for water vapour that air can hold. At this stage, the air is said to be saturated. The pressure exerted by water vapour under such a saturated condition is called saturation vapour pressure. When temperature increases, value of *saturation vapour pressure* also increases. The pressure exerted by water vapour actually present in air is called the actual vapour

pressure of air or simply vapour pressure of air.

The ratio of actual vapour pressure to saturation vapour pressure under fixed conditions of temperature expressed in percentages is known as *relative humidity* which is used universally as a measure of humidity.

— Another measure of humidity is the *dew point temperature* which is the temperature at which air would become saturated if cooled at constant pressure without addition or removal of water vapour. Thus, the actual vapour pressure is equal to the saturated vapour pressure at the dew point temperature. The closer the dew point to air temperature, the nearer is the air to the saturated condition.

— *What is wet bulb temperature and how it is measured?*

The wet bulb temperature of moist air at a given pressure and temperature is the temperature attained when the air is brought to saturation by evaporating water into it. The wet bulb temperature is measured by the wet bulb thermometer fixed inside the Stevenson screen. The bulb of this thermometer is covered by a piece of muslin cloth which is continuously kept moist by means of four strands of cotton thread, the ends of which are dipped into a small glass vessel containing either distilled water or rain water. Use of non-distilled water may cause incrustation of salts over the bulb in course of time.

— *What are the principles of wet bulb thermometer?*

When water evaporates, it requires energy for converting itself into vapour. The heat energy required for this change of state is known as latent heat of vaporisation. This heat energy will not cause any change in temperature. Latent heat of vaporisation varies from 540 to 600 calories for different temperature ranges for converting one gram of water into water vapour.

In case of wet bulb thermometer, when water evaporates from the wet surface, the latent heat requirement is drawn from the bulb of the thermometer and so the mercury column comes down indicating a reduction of temperature. This type of evaporation and consequent reduction in mercury level continue till the air just surrounding the wet bulb becomes saturated. The final temperature so attained is known as wet bulb temperature. If the air is originally saturated, evaporation can not occur and there is no cooling. Thus, under the saturated conditions both the dry and wet bulb thermometer readings would remain the same. But when the air becomes more and more

dry, the difference between dry and wet bulb thermometer would increase. Thus, the depression of wet bulb (viz. Dry bulb temperature—wet bulb temperature) is a good measure of air humidity.

—*How are the dew point temperature and relative humidity calculated from the wet bulb and dry bulb temperature?*

From the dry bulb and wet bulb temperature readings, the dew point temperature and relative humidity can be obtained by reference to Hygrometric tables. If the height of the place of observation is less than 1500′ (457.5 m), 1000 mb Hygrometric tables are to be used and for higher station, 900 mb Hygrometric tables are to be used.

Dew point temperature and relative humidities corresponding to specified values of dry and wet bulb temperatures are given in the above mentioned 'Hygrometric tables' at intervals of 0.2°C. While using the tables, interpolation to the nearest 0.1°C has to be done, wherever necessary. The following example would illustrate the procedure.

Example: Dry Bulb temperature = 34.5°C
Wet Bulb temperature = 29.7°C

(a) Computation of relative humidity :

Referring to 1000 mb Hygrometric table, the relative humidity values of the corresponding temperatures are as follows:

		Wet Bulb	
		29.6° C	*29.8° C*
Dry Bulb	34.4°C	69	70
	34.6°C	68	69

For this, firstly we have to interpolate for dry bulb temperature as follows:

		Wet Bulb	
		29.6° C	*29.8° C*
Dry Bulb	34.5°C	68.5	69.5

So for wet bulb temperature of 29.7°C relative humidity is 69%

(b) Computation of dew point temperature :

The values from the tables are as follows:

		Wet Bulb	
		29.6° C	*29.8° C*
Dry Bulb	34.4°C	27.9	28.2
	34.6°C	27.8	28.1

Interpolating for dry bulb temperatures, we get:

		Wet Bulb	
		29.6° C	*29.8° l C*
Dry Bulb	34.5°C	27.9	28.1

In this connection pupil should note that if any digit is followed by 0.5, it should be rounded off to the next higher digit only when the digit is even, and when the digit is odd, it remains the same. For instance 8.5 should be rounded off as 9 and 9.5 also as 9. This procedure is followed in order to avoid systematic over estimation during rounding off

So final interpolated value of dew point temperature is 28.0°C for the wet bulb temperature of 29.7°C.

—How are vapourpressure and saturation vapour pressure deficit computed?

At the outset, dew point temperature should be calculated from the Hygrometric tables following the above mentioned procedure.

Since the vapour pressure is the saturation vapour pressure at the dew point temperature, the vapour pressure can be computed by noting from the saturation vapour pressure table (Table 3.2.1), the value corresponding to the dew point temperature.

For instance, in the previous example dew point temperature is 28.0° C. By referring to the corresponding values in saturation vapour pressure table, we get vapour pressure as 28.4 mm of mercury.

Saturation vapour pressure deficit is defined as the difference between the saturation vapour pressure and actual vapour pressure of the air. In the above example, the saturation vapour pressure deficit can be computed as follows:

Saturation vapour pressure = 41.0 mm of mercury

(Obtained by referring to the saturation vapour pressure table 3.2.1 entry corresponding to dry bulb temperature of 34.5°C).

Actual vapour pressure = 28.4 mm of mercury

So, saturation vapour pressure deficit

= 41.0 - 28.4

= 12.6 mm of mercury.

Table 3.2.1 **Saturation vapour pressure in mm of Hg in terms of mean air temperature in °C and tenths.**

Temp. °C	*0.0*	*0.1*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*
5	6.5	6.6	6.6	6.7	6.7	6.8	6.8	6.9	6.9	7.0
6	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.4	7.4	7.5
7	7.5	7.6	7.6	7.7	7.7	7.8	7.8	7.9	7.9	8.0
8	8.1	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5
9	8.6	8.7	8.7	8.8	8.9	8.9	9.0	9.0	9.1	9.1
10	9.2	9.3	9.3	9.4	9.5	9.5	9.6	9.7	9.7	9.8
11	9.8	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.4	10.5
12	10.5	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.1	11.2
13	11.2	11.3	11.4	11.5	11.5	11.6	11.7	11.8	11.8	11.9
14	12.0	12.1	12.1	12.2	12.3	12.4	12.5	12.5	12.6	12.7
15	12.8	12.9	13.0	13.0	13.1	13.2	13.3	13.4	13.5	13.5
16	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.3	14.4
17	14.5	14.6	14.7	14.8	14.9	15.0	15.1	15.2	15.3	15.4
18	15.5	15.6	15.7	15.8	15.9	16.0	16.1	16.2	16.3	16.4
19	16.5	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4
20	17.5	17.7	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5
21	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.5	19.6	19.7
22	19.8	19.9	20.1	20.2	20.3	20.4	20.6	20.7	20.8	20.9
23	21.1	21.2	21.3	21.5	21.6	21.7	21.9	22.0	22.1	22.3
24	22.4	22.5	22.7	22.8	22.9	23.1	23.2	23.3	23.5	23.6
25	23.8	23.9	24.1	24.2	24.3	24.5	24.6	24.8	24.9	25.1
26	25.2	25.4	25.5	25.7	25.8	26.0	26.1	26.3	26.4	26.6
27	26.7	26.9	27.1	27.2	27.4	27.5	27.7	27.9	28.0	28.2
28	28.4	28.5	28.7	28.9	29.0	29.2	29.3	29.5	29.7	29.9
29	30.1	30.2	30.4	30.6	30.7	30.9	31.1	31.3	31.5	31.7
30	31.8	32.0	32.2	32.4	32.6	32.8	32.9	33.1	33.2	33.5
31	33.7	33.9	34.1	34.3	34.5	34.7	34.9	35.1	35.3	35.5
32	35.7	35.9	36.1	36.3	36.5	36.7	36.9	37.1	37.3	37.5
33	37.7	37.9	38.2	38.4	38.6	38.8	39.0	39.3	39.5	39.7
34	39.9	40.1	40.4	40.6	40.8	41.0	41.3	41.5	41.7	41.9
35	42.2	42.4	42.7	42.9	43.1	43.4	43.6	43.9	44.1	44.3
36	44.6	44.8	45.1	45.3	45.6	45.8	46.1	46.3	46.6	46.8
37	47.1	47.3	47.6	47.9	48.1	48.4	48.6	48.9	49.2	49.4
38	49.7	50.0	50.2	50.5	50.8	51.1	51.3	51.6	51.9	52.2
39	52.5	52.7	53.0	53.3	53.6	53.9	54.2	54.5	54.7	55.0
40	55.3	55.6	55.9	56.2	56.5	56.8	57.1	57.4	57.7	58.1

—*What are mist and fog?*

When there is a suspension of water vapour and dust particles in air, there is atmospheric obscurity. If the relative humidity is less than 70 per cent, the dust particles are dry and we call the phenomenon as

haze. When the relative humidity becomes more than 70 per cent, obscurity increases due to condensation of water vapour into minute water droplets. This is called *mist.* In both the cases of haze and mist, visibility is more than 1 km which means that the objects beyond 1 km can be clearly seen.

When the air is further cooled and the relative humidity increases, mist thickens into *fog* and the visibility is less than 1 km. In case of thick fog the visibility is reduced to even less than 200 metres. While the size of the condensed water droplets in case of fog varies from 1 micron to 10 microns, the size of the water droplets in mist is less than 1 micron (1 micron = 10^{-6}m).

3.4 Precautions :

- — Use distilled water or rain water for the wet bulb thermometer and keep the container bottle clean.
- — Cover the bulb with only one fold of muslin cloth tied with 4 strands of darning cotton and trim off excess muslin cloth.
- — The bottle should have a small neck so that the air inside the screen may not be moistened by evaporation of water from the vessel.
- — Place the bottle on one side of the wet bulb away from the dry bulb and not directly below the wet bulb.
- — Keep muslin and cotton threads clean and free from dust or grease.
- — Change muslin cloth and threads immediately after a dust storm.
- — Inspect wet bulb periodically and if the wet bulb develops a white coating due to incrustation of salts, clean it with a lemon or dilute acid.
- — Avoid parallax error while reading the thermometer and apply index correction, if any.

3.4 Materials required :

i. Dry bulb and wet bulb thermometers installed in a Stevenson screen

ii. Hygrometric tables

iii. Saturation vapour pressure table

3.5 Procedure :

— Open the Stevenson screen.

— Note the reading of dry bulb thermometer correct to 0.1°C.
— Note the reading of wet bulb thermometer correct to 0.1°C.
— Read from Hygrometric tables dew point temperature and relative humidity values, corresponding to observed dry bulb and wet bulb temperature readings after carrying out necessary interpolation.
— Compute vapour pressure from the dew point temperature obtained, by using the saturation vapour pressure table.
— Compute the saturation vapour pressure corresponding to the dry bulb temperature from the same table.
— Calculate the saturation vapour pressure deficit, by the method given already.

3.6 Observations :

The pupil should record the following observations:

Dry bulb temperature
Wet bulb temperature
Vapour pressure
Saturation vapour pressure
Saturation vapour pressure deficit

3.7 Expected behavioural outcomes :

The pupil will be able to :

— recall the different measure of humidity;
— explain the significance of the wet bulb temperature;
— maintain wet bulb thermometer;
— measure wet bulb temperature;
— compute dew point temperature and relative humidity from observed wet and dry bulb temperature readings;
— calculate vapour pressure, saturation vapour pressure and saturation vapour pressure deficit values.

Grade

The teacher should evaluate the pupil for the above abilities.

3.8 Questions :

i. How do you calculate relative humidity from :

a) Dry and wet bulb thermometer readings

b) Vapour pressure and saturation vapour pressure

ii. Distinguish between mist, fog and haze.

iii. Find the dew point temperature, relative humidity, and saturation vapour pressure deficit from the following data:

	Dry bulb temperature	*Wet bulb temperature*
(a)	38.6°C	25.5°C
(b)	27.3°C	21.7°C
(c)	21.7°C	18.6°C

iv The following data pertains to a Northern Indian Station.

Month	*Mean vapour pressure*	*Mean temperature*
January	6.8 mm of Hg	16.0°C
April	12.1 mm of Hg	32.3°C

Will relative humidity be higher in January or April? Why?

4. Activity Unit

MEASUREMENT OF WIND

4.1 Instructional objectives :

The pupil should be able to:

— recall the instruments used to find out the wind direction and wind speed;
— determine wind direction;
— measure wind speed;
— compute the mean daily wind speed.

4.2 Relevant information :

— What is wind?

Wind is the air in horizontal motion caused due to differences in atmospheric pressure. Wind has to be specified by its direction and speed. The movement of wind is almost horizontal and the vertical component is very small, being about 1/100th of the horizontal component. So by wind, we generally mean only the horizontal component of the wind.

— Wind instruments

The common instrument to determine wind direction is Wind vane (Fig. 4.2.1). This instrument indicates the direction from which wind blows. It is a balanced lever which turns freely about a vertical axis. One end of the level exposes a broad surface to the wind, while the other end is narrow and points to the direction from which the wind blows. This narrow end is in the form of an arrow head. Under this movable system there are eight fixed rigid bars which are set to the eighth cardinal directions - North, North-east, East, South-east, South, South-west, West and North-west.

The arrow head of the wind vane points to the direction of wind and it is to be read from the wind vane to the nearest of the sixteen points of the compass.

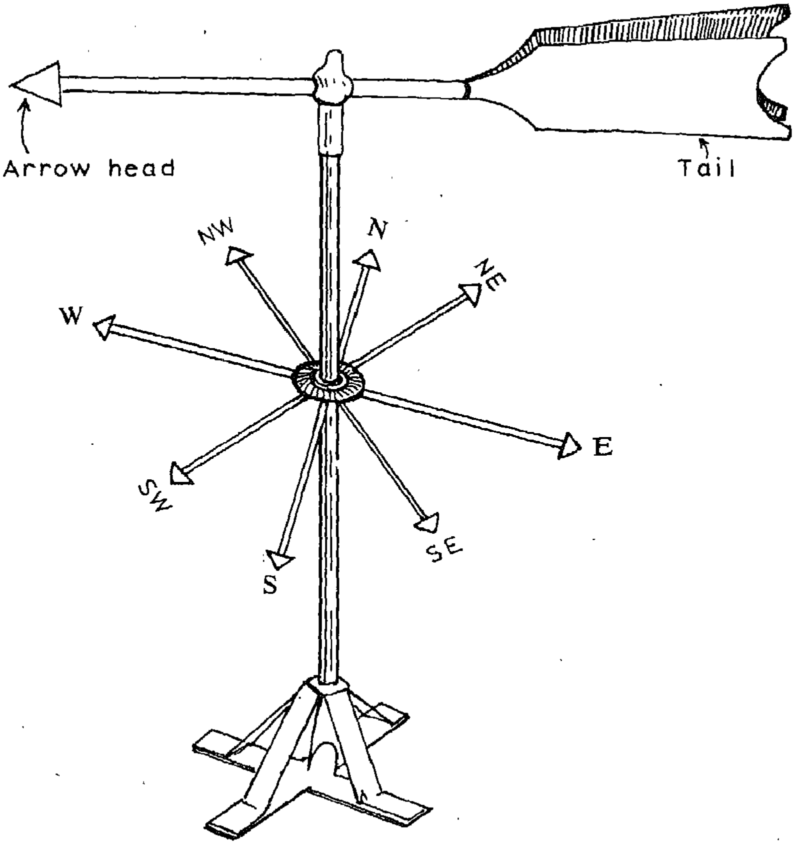

Fig. 4.2.1 WIND VANE

Wind speed is measured by Cup counter anemometer (Fig. 4.2.2). This instrument consists of four hemispherical cups (sometimes three) fixed at the end of metal arms from a central point. The cup wheel is pivoted at the centre to a vertical spindle passing through a brass tube attached to the anemometer box. The cup is set in motion due to the pressure difference occurring between the two faces of the cup. The vertical spindle about which the cups rotate, is connected to a mechanical counter through a gear system from which the number of rotations made by the cups in a chosen interval of time can be counted. The counter is directly calibrated in kilometres.

In an agro-meteorological observatory, wind instruments

should be installed at a site which is as open as possible. There should not be any tall trees or buildings nearby. The wind instruments are installed on pillars so that the height of the centre of anemometer cup or the arrow head should be 10′ (3.05 metres) above the ground. The minimum exposure criterion for the wind instruments is that any obstruction should be away from the wind instruments by atleast 10 times the height of the obstruction.

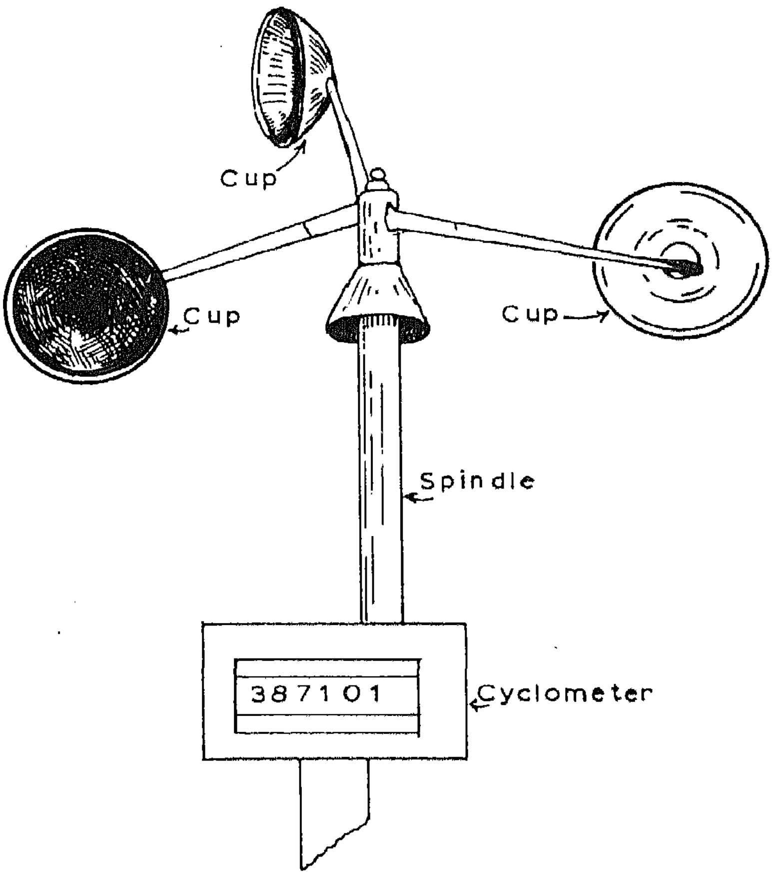

Fig. 4.2.2 CUP COUNTER ANEMOMETER

For the sake of maintenance, the screw cap of the wind vane should be removed and a few drops of clock oil should be put every

fortnight. For anemometer also, lubrication by clock oil should be done every week.

— *How is wind direction measured at the time of observation?*

The wind direction is read by noting the direction to which the arrow head points. The wind vane should be watched for a few minutes so that the mean direction can be identified. The direction should be read from the wind vane to the nearest of the sixteen points of compass. For example if the arrow head is pointing towards the middle of the region between North (N), and North-west (NW), the direction should be read as North - North-west (NNW).

— *How is wind speed measured at the time of observation?*

To determine wind speed at the time of observation, two successive readings of the anemometer should be taken at an interval of 3 minutes. The difference between the two readings when multiplied by 20 will give the wind speed in kilometres per hour (kmph), if the anemometer is calibrated in kilometres.

For example : If the first anemometer reading is 3954.6 and the second reading is 3955.4, the wind speed is given by :
20 × (3955.4–3954.6) = 20 × 0.8 = 16.0 kmph.

— *How is mean daily wind speed calculated ?*

The mean daily wind speed is calculated at the I hour of observation viz., 7 hrs local mean time (LMT) at the agromet observatories. The anemometer reading of 7 hrs LMT of the previous dav is subtracted from 7 hrs. LMT reading of the current day and the difference is divided by 24 so that mean daily wind speed in kmph can be obtained. Thus, mean daily wind speed on a particular date corresponds to the 24 hour period ending at 0700 hours local mean time of that date. The following example will illustrate this procedure.

Anemometer reading at I hr of 17.6.82	..	2878.3
Anemometer reading at I hr of 16.6.82	..	2594.7
	Difference :	283.6

Mean daily wind speed on 17.6.82 is given by 283.6/24 = 11.8 kmph.

4.3 Precautions :

— Make sure that the wind vane moves freely before taking the reading.
— During occasions of light wind when wind vane does not respond readily, give a slight turn to wind vane by hand and allow it to take up the direction of wind.
— In order to verify the direction given by the wind vane, compare the same with the approximate direction determined either by facing the direction of wind or by letting of small bits of paper.

4.4 Materials required :

i. Cup counter anemometer
ii. Wind vane.

4.5 Procedure :

— Watch the wind vane for a few minutes and identify the direction.
— Read the direction to which the arrow head points, nearest to the sixteen points of the compass.
— Note the initial reading of the anemometer as well as the time accurately.
— Note the final reading of the anemometer after 3 minutes.
— Subtract the initial reading from the final reading and multiply by 20 to get the instantaneous wind speed at the time of observations in kmph.
— Subtract the anemometer reading at 7 hrs LMT (Local Mean Time) of the previous day from that at 7 hrs LMT of the observation date and divide the difference by 24. This will give the mean daily wind speed for the observation date.

4.6 Observations :

The pupil should take and record the following observations :
— Wind directions at the time of observation.
— Wind speed at the time of observation.
— Daily mean wind speed.

4.7 Expected behavioural outcomes :

The pupil will be able to :

Grade

— determine the wind direction at the time of observation;

— find out the wind speed at the time of observation;

— compute daily mean wind speed.

The teacher should evaluate the pupil for the above abilities.

4.8 Questions :

i. How is the wind direction determined correct to the sixteen points of compass?

ii. Describe a cup counter anemometer.

iii. Calculate the wind speed at the time of observation on 4.6.1982 and the mean daily wind speed on 5.6.1982 with the following data from cup counter anemometer :

Date	*Time*	*Reading*
4.6.1982	0710 hrs. IST*	2358.9
	0713 hrs. IST.	2359.4
5.6.1982	0710 hrs. IST.	2503.1

* At the station concerned, 0710 hrs. I.S.T. is equivalent to 0700 hrs. L.M.T.

iv. Draw a diagram showing all the cardinal directions of the sixteen points of the compass.

5 Activity Unit

MEASUREMENT OF SUNSHINE AND CLOUD AMOUNT

5.1 Instructional objectives :

The pupil should be able to :

- explain the importance of sunshine and cloud data for agriculture;
- measure daily hours of sunshine with the help of a sunshine recorder;
- estimate cloud amount.

5.2 Relevant information :

— *What is the importance of sunshine and cloud data for agricultural purposes?*

Crops obtain energy necessary for life directly from sunlight. They convert solar energy into chemical energy during the process of photosynthesis. Large amounts of energy are also required during the process of transpiration of crops. These are also derived from the solar energy. Infestation of pests and diseases is also generally associated with the occurrence of prolonged periods of continuous cloudy days during the crop growing season.

Since the recording of solar radiation requires advanced instrumentation such as pyranometer and potentiometric recorder etc. which are not generally available at many stations, the collection of sunshine data, with the help of sunshine recorder would be essential. It is possible to estimate solar radiation from the sunshine data.

Even if the sunshine recorder is not available, it is possible to estimate solar radiation from the cloud amount data recorded during different times of observations.

— *What is the method of measuring sunshine ?*

The sunshine is measured by means of the Campbell—Stokes

sunshine recorder (Fig. 5.2.1). This consists of a glass sphere of 10 cm

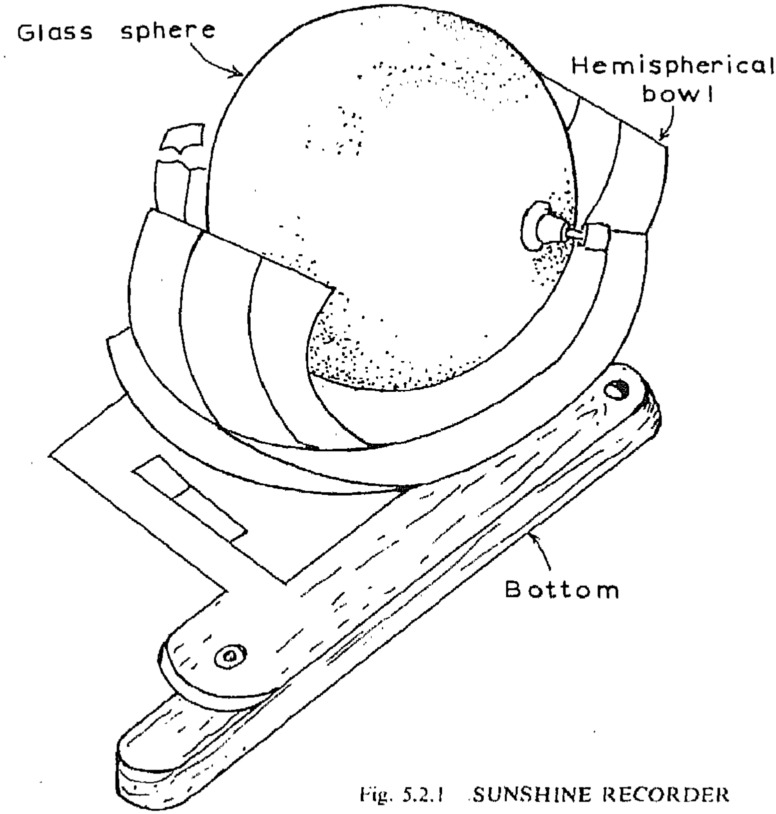

Fig. 5.2.1 SUNSHINE RECORDER

diameter, mounted concentrically in a section of spherical bowl, the diameter of which is such that the sun's rays are focussed sharply on a card (Fig. 5.2.1a) held in the grooves cut into the bowl. There are

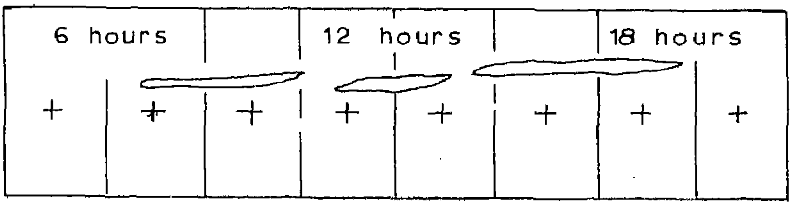

Fig. 5.2.1a SUNSHINE CARD

three overlapping pairs of grooves each to take cards suitable in shape for different seasons of the year. The sunshine recorder is installed on a masonry pillar of 5′(1.52 m) or 10′(3.04 m). There should not be any obstruction having an elevation of 3^0 above the horizon.

Three types of cards namely the short curved cards from 13th October to last date of February, the long curved cards from 13th April to 31st August and straight cards for other seasons are used. While inserting the new sunshine card, its 12 hr line should be adjusted to coincide with the noon line engraved on the bowl and the clamping screw should be tightened. The card is subdivided into hourly intervals, As the sun moves across the sky, its focussed image burns a trace on the card, so that by measuring the trace for the whole day, the duration of sunshine during the day can be accurately recorded. For this purpose, a special plastic scale is provided in which the subdivisions of the hour are also marked. By keeping the plastic scale on the trace, the total duration of the intermittent burns of the card within an hour can be added upand thus,the total duration of sunshine can be obtained correct to 0.1 of an hour. The hours marked in the sunshine card refer to local mean time (L.M.T) of the station. Thus sunshine is measured in number of hours per day. For each day's observation, sunshine cards should be inserted in the recorder before sunrise and removed after sunset.

— *How is the cloud amount estimated ?*

The international unit for estimating the cloud amount is the "Okta" or eighth of the sky. The assessment of the total amount of cloud therefore consists in estimating how much of the total apparent area of the sky, to the nearest eighth, is covered with cloud. For this purpose, the pupil should observe the sky and imagine it to be divided into four quadrants. By imagining the clouds that are scattered in different parts of the sky to be put together, he should estimate how many quadrants the total cloud occupies. The amount of cloud is to be taken as "Zero" only if the sky is completely cloudless and 'Eight' when the sky is completely overcast without gaps of any kind.

5.3 Precautions :

- Do not clean the glass bowl of the sunshine recorder with any cloth or material which may abrade the surface. Avoid excessive vigour in polishing.
- Remove immediately any deposit such as dew, frost, snow or bird dropping.

— If the trace is not parallel to the central line of the card, or if the intensity of the trace is too high or too low, carry out levelling and other adjustments of the recorder.
— Use the sunshine cards appropriate to the seasons.
— While estimating the cloud amount, give equal weightage to the clouds near the horizon as well as those close to the zenith.

5.4 Materials required :

i. Campbell—Stokes sunshine recorder
ii. Sunshine cards
iii. Special plastic scale for measuring sunshine in fractions of hour.

5.5 Procedure

— Select the appropriate new card corresponding to the season concerned.
— Insert the new sunshine card in the appropriate groove of the recorder and adjust it so that its 12 hr line coincides with the noon mark engraved on the bowl.
— Remove the burnt card in the evening after sunset and mark the date of observation on the reverse of the card.
— Tabulate the amount of sunshine recorded during each hour of the day from sunrise to sunset using the special plastic scale.
— Add up the values for all the hours and determine the total duration of sunshine hours for the day.
— Observe the sky from a location in which the widest possible view of the sky can be obtained.
— Estimate the total amount of clouds in the sky in Oktas.

5.6 Observations :

The pupil should record the following observations :
— Duration of sunshine during each hour of the day.
— The total cloud amount in Oktas at the time of observation.

5.7 Expected behavioural outcomes :

The pupil will be able to :

	Grade
— explain the importance of sunshine and cloud	

data in agriculture;
— measure daily hours of sunshine;
— estimate the cloud amount in Oktas.

The teacher should evaluate the pupil for the above abilities.

5.8 Questions :

i. Give two processes in agriculture in which use of solar energy is important.
ii. In the absence of solar radiation data, from which factors it can be estimated?
iii. What are the different types of cards used for the sunshine recorder and the periods of the year for which they are used?
iv. Estimate the daily hours of sunshine from the given cards. (For this, the teacher should provide the pupil with cards, showing typical traces of cloudy days and clear days).
v. If during the crop growing season number of cloudy days occur continuously, what would be its effect on different biological processes of the crop?

6. Activity Unit

MEASUREMENT OF EVAPORATION

6.1 Instructional objectives :

The pupil should be able to :

recall the meteorological factors that influence the water loss by evaporation;

measure evaporation by means of pan evaporimeter.

6.2 Relevant information :

— *What is evaporation and what are the factors that influence it?*

Evaporation is one of the important aspects of the hydrologic cycle by which water from the earth's surface is transferred to the atmosphere in the form of water vapour. Measurement of evaporation is of great importance in agricultural and hydrometeorological studies. The rate of evaporation is defined as the amount of water lost by evaporation from a unit area of a surface in unit time and is expressed in depth units (mm/day) just like rainfall.

Evaporation is dependent on a number of factors such as (a) total radiation, (b) temperature of the evaporating surface and that of air, (c) wind speed, (d) vapour deficit and (e) nature of surface etc.

— *Description of pan evaporimeter*

Evaporation is measured by means of pan evaporimeter (Fig. 6.2.1). The Class 'A' pan evaporimeter which is commonly used in India, consists of a large cylindrical pan made of copper with 120 cm diameter and 25 cm depth. The pan is made of 20 gauge copper sheet tinned inside and painted white outside. A still well is provided inside the pan so that there would be undisturbed water surface inside that well and ripples would be broken. It consists of a brass cylinder mounted on a heavy circular base provided with three circular holes at the bottom. The reference point is provided by a brass rod fixed at the centre of the still well.

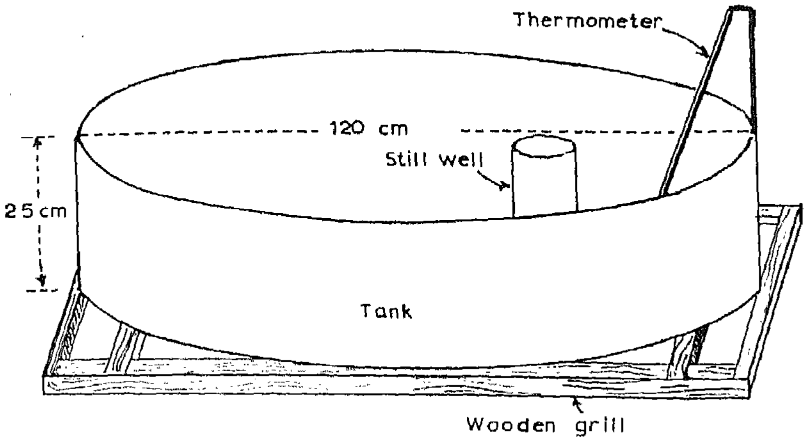

Fig. 6.2.1 CLASS 'A' PANEVAPORIMETER

The top of the rod tapers to a point and is exactly 190 mm above the base of the pan. The pan is filled up with clean water till the water level just touches the tip of the rod. The pan rests on a white painted wooden grill so that the bottom of the pan would be above the surface of water in rainy weather. The wooden grill also helps in reducing the conduction of heat from the surrounding soil. The pan is provided with a standard wire mesh to prevent the loss of water from the pan by external agencies such as birds, animals, etc.The water temperature of the pan is measured by means of a thermometer which is just immersed below the water level in the pan.

For measuring evaporation a graduated measuring cylinder (Fig. 6.2.2) made of brass is also provided with the instrument. It has

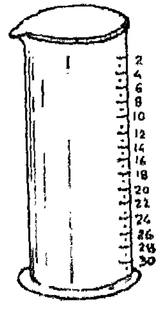

Fig. 6.2.2 GRADUATED MEASURING CYLINDER

a scale 0-20 cm, engraved inside it along its height. The cross sectional area of the measuring cylinder is exactly 1/100th of the area of pan. The evaporimeter should be installed at an open site with no obstruction casting shadow on the pan. The site should be free from flooding or water logging even during heavy rains. The pan should be placed on the wooden grill kept on a firm foundation so that the edge of the pan is level and is exactly at 36 cm above the ground.

-- *How daily evaporation is measured ?*

The observations of evaporation should be made daily at 0830 hrs IST. Initially the water is filled up to the fixed point tip. Due to evaporation, the water level will normally be below the tip of the rod at the time of observation, then add water to the evaporimeter using the measuring cylinder till the water level once again coincides with the tip of the reference point. In the measuring cylinder the graduation runs from top to bottom. Hence the amount of water added, which is equal to the evaporation that has occurred during the day can be directly measured. For example, if on a particular day three full cylinders of water and 4 cm of water i.e., 64 cm has been added to bring the water level to the reference point, the actual evaporation can be determined by dividing the amount of water added by 100, since the area of the pan is 100 times that of the area of the base of the measuring cylinder. Thus, the evaporation during day is 64cm/100 = 6.4 mm. The evaporation should be recorded correct to 0.1 mm. In case the evaporation observation has been taken during 1400 hrs. L.M.T. (II hour) of the previous day, the evaporation recorded during that hour should be added to the evaporation reading at 0830 hrs IST of date (which represents evaporation from 1400 hrs LMT of the previous day to 0830 hrs IST of the day so that we can get the total daily evaporation for 24 hrs ending 0830 hrs IST of the day.

If rainfall has occurred after the previous observation and that rainfall has exceeded evaporation during that period, water has to be removed from the pan till the water level reaches the reference level indicated by the tip of the rod.

If the rainfall that has occurred during the period is less than the evaporation, slight water has to be added to the pan to bring it to the reference level. But, while calculating the total evaporation, not only the water added, but the rainfall that has occurred should be taken into account.

The following examples would illustrate these procedures :

i. Water added at 0830 hrs IST on 4-11-1982 to bring the water level to the reference point is 51 cm. Rainfall from 0830 hrs IST on 3-11-82 to 0830 hrs IST on 4-11-82 is Nil. Evaporation on 4-11-1982 = 51 cm / 100 = 5.1 mm

ii. Water removed at 0830 hrs IST of 10-7-82 = 64 cm. This amounts to a change in water level of 6.4 mm. The rainfall recorded at 0830 hrs IST of 10-7-1982 is 8.4 mm. Had there been no rain, the level would have risen by 8.4 mm. So the evaporation for the day is— 8.4 – 6.4 = 2.0 mm.

iii. The water added at 0830 hrs IST on 5-6-82 is 23 cm. This amounts to a change in water level of 2.3 mm. If the rainfall recorded at 0830 hrs IST on 5-6-1982 is 1.6 mm, the actual evaporation is equivalent to the sum of rainfall and the decrease in water level. So the evaporation for the day : 2.3+1.6 = 3.9 mm.

6.3 Precautions :

— Inspect the pan periodically for leaks.

— Check periodically and ensure that the wooden platform and the bottom of the tank are perfectly horizontal and the height of the rim is 36 cm above the ground level.

— Clean the pan atleast every fortnight and fill it up with fresh water.

— When there is a likelihood of heavy rain which may cause overflowing of the pan, remove enough water and make entries regarding the same in the observation book.

— Paint the outside of the pan with white paint and do tinning inside once every year.

— Use water that has been stored in a reservoir for refilling so that its temperature will be same as that of the pan.

6.4 Materials required :

i. Class 'A' Pan evaporimeter

ii. Still well

iii. Wooden frame

iv. Measuring cylinder

v. Thermometer

6.5 Procedure :

— Note the water temperature correct to 0.1°C.

— Note the bottle level in the still well of the pan.

— If the water level is below the tip of the rod add sufficient water slowly with the help of the measuring cylinder, so that the water level again coincides with the reference level.

— Note the amount of water added by taking into account the number of cylinders of water added and parts thereof.

— Divide the amount of water (which is measured in cm) by 100 and record the quotient as the evaporation (in mm) for the 24 hrs ending at 0830 hrs IST of the day.

— If rainfall has occurred during 24 hrs ending 0830 hrs IST and still the water level has fallen below the reference point and water has to be added to bring the water level to the reference level, mm equivalent of this amount of water should be added to the rainfall amount in mm to get the total evaporation for the day.

— If, however, the rainfall has been heavy and the water level has gone above the reference point at the time of observation, remove water with the help of the measuring cylinder, in order to bring the water level back to the reference point. Subtract from the rainfall the mm equivalent of the removed water in order to get the total evaporation for the day.

— If on any day, due to occurrence of very heavy rainfall, the water level has risen upto the rim of the pan and some water has over flown, evaporation for that day cannot be determined. So, entry "over flown" should be made in the observation register.

6.6 Observations :

The pupil should record the following observations :

— Temperature of water in the pan

— Amount of water added or removed to bring back the water level to the reference point.

— Amount of rainfall during the past 24 hrs.

6.7 Expected behavioural outcomes :

The pupil will be able to :

	Grade
— recall the meteorological factors that influence water loss by evaporation;	

– explain the meteorological factors that influence water loss by evaporation;
– measure evaporation from Class 'A' Pan evaporimeter during rainy and non-rainy days.

The teacher should evaluate the pupil for the above abilities.

6.8 Questions :

i. What are the various meteorological factors that influence evaporation?

ii. What is the difference in procedure to measure evaporation on rainy and non-rainy days?

iii. Calculate the Pan evaporation with the following data:

a)	Water added	48 cm
	Rainfall for the past 24 hrs	Nil
b)	Water added	21 cm
	Rainfall for the past 24 hrs	5.5 cm
c)	Water removed	141 cm
	Rainfall for the past 24 hrs	16.7 mm

iv. The following are the mean data recorded on 2 days at a station. State on which day pan evaporation will be more. Why?

	Day I	*Day II*
Mean air temperature ..	30°C	29.8°C
Mean vapour pressure ..	14 mm of Hg	20 mm of Hg
Mean wind speed	12 kmph	5 kmph

7. Activity Unit

MEASUREMENT OF DEW

7.1 Instructional objectives:

The pupil should be able to :

— explain the meteorological conditions under which dew and frost occur and their significance in agriculture;

— measure the dew with the help of Duv-Devani Dew gauge.

7.2 Relevant information :

— How dew is formed and what are the meteorological conditions associated with the formation of dew?

On a clear night, the ground temperature falls because of its continuous loss of heat by long-wave radiation. The air in contact with earth's surface is chilled and when the temperature falls below the dew point temperature (See Activity Unit-3) of the air, dew is deposited. Dew is an important source of soil moisture during non-rainy seasons especially in arid and semi-and regions. The bare soil cools more slowly than vegetation because of the upward flow of heat from below in case of bare soil and the existence of thermal insulation by air within the crop canopy. Thus, dew forms more on the vegetation than on the bare soil. Dew formation would be more on calm or light windy days when the mixing of air would be minimum. The favourable meteorological conditions for the dew formation are as follows:

a) Clear night sky (to allow maximum loss by long-wave radiation).

b) Moist air from sunset onwards (Relative humidity greater than 75%).

c) Calm or light winds.

— What is frost and how it is formed?

As explained under dew, on clear nights with calm or light winds, the air near the ground cools. If this cooling is rapid and

condensation takes place below 0°C, frost forms. Under such conditions, the moisture changes from vapour state directly to ice state. This generally forms during winter when cold waves occur. This is a hazard for agricultural and horticultural crops.

— *How is dew measured ?*

Dew is measured by Duv Devani dew gauge (Fig. 7.2.1). This consists of a rectangular wooden block (32 cm × 5 cm × 2.5 cm) coated with red paint which favours retention of dew deposits on it. The dew gauge is exposed in the open on a stand at about sunset. In the early morning, just at the time of sunrise, the dew formed on the gauge is observed and compared with a set of photographs contained in the dew album, which represent different dew scales and thereby the actual dew scales for the day is determined. The water equivalents in mm of these dew scales vary from 0.02 mm for dew scale No. 1 to 0.35 mm for dew scale No. 8. Thus, knowing the dew scale number, it is possible to measure dew. In order to measure the dew formation at different heights, the dew gauges are fixed on a stand at heights of 5, 25, 50 and 100 cm above ground. There are also patterns in the dew album for the occurrence of dew and rain and for the occurrence of rain only.

7.3 Precautions :

- Do not touch the surface of dew gauge with grease or dusty fingers.
- After taking the dew observation, keep the dew gauge inside. Otherwise the sunlight will damage the sensitive surface of the dew gauge.
- After recording the observations, do not wipe off the water deposits but remove by swinging.

7.4 Materials required :

i. Duv Devani dew gauge
ii. Iron stand for dew gauge
iii. Dew Album

7.5 Procedure :

Expose the dew gauge in the open on the stand after sunset. Observe the pattern of dew on the dew gauge at about the timeof sunrise.

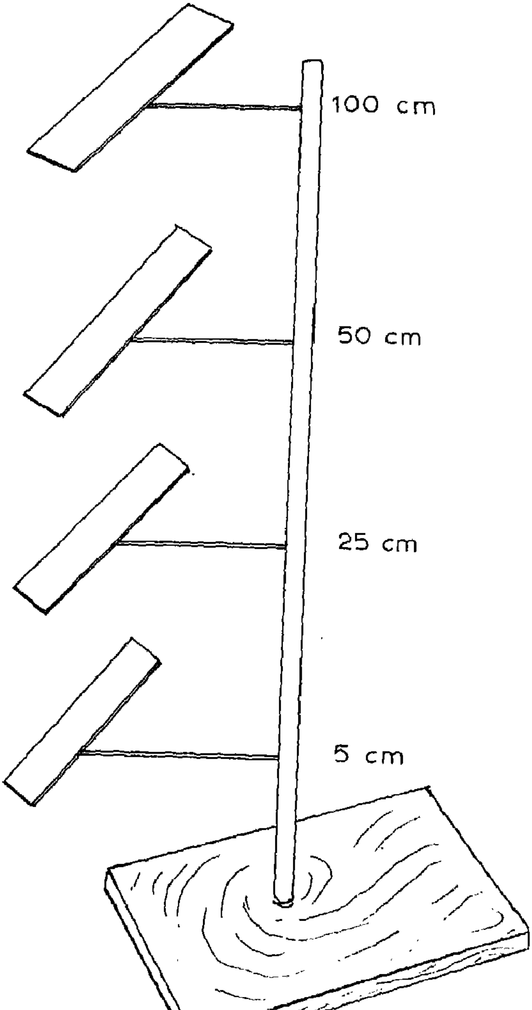

Fig. 7.2.1 DUV-DEVANI DEW GAUGE

Compare the dew pattern with the photographs in the dew album and select the photograph which closely resembles the observed dew pattern.

Note the dew scale number of the photograph selected and enter the water equivalent (in mm) as dew.

7.6 Observations :

The pupil should record the following :

- Amount of dew deposited at different heights above the ground.

7.7 Expected behavioural outcomes :

The pupil will be able to :

— explain the favourable weather conditions for the formation of dew and frost;

-- measure dew by the Duv Devani dew gauge.

Grade

The teacher should evaluate the pupil for the above abilities.

7.8 Questions :

i. What are the meteorological conditions that favour dew formation?

ii. When does frost occur?

iii. Give the significance of dew and frost in agriculture.

8. Activity Unit

MEASUREMENT OF SOIL TEMPERATURE

8.1 Instructional objectives :

The pupil should be able to :

explain the importance of soil temperature in crop growth;
measure soil temperature at different depths of the soil.

8.2 Relevant information :

— *What is the importance of soil temperature in crop growth?*

The surface of the earth gets heated up during the day and gets cooled during the night causing diurnal changes in the top layers of the soil. The crops have their root systems in these layers and extract plant nutrients and water from these layers. Since the heat regimes of these layers are governed by the soil temperatures, the measurement of soil temperature becomes extremely important. During crop germination also soil temperatures play a vital role.

The moisture movement in vapour phase is mostly governed by the temperature gradients in soil. The condensation of the water vapour in the air in the form of dew or frost also occurs due to the excessive cooling of the earth surface due to emission of longwave radiation by it. Thus, knowledge of soil temperatures is extremely important.

— *How is soil temperature measured?*

The soil temperature is measured by soil thermometers (Fig. 8.2.1). These are mercury-in-glass thermometers of the enclosed scale type. There is a bend of 120°C just above the bulb, the rest of the stem being straight, so that when the soil thermometer is installed at a particular depth of the soil, the bulb rests horizontally. The inclination of the stem at 120° also facilitates the reading of the scale. In these thermometers there are graduations for every degree centigrade and the graduations begin from the distance of 6.5 cm,

17.5 cm and 35.0 cm from the bulb for the 5, 15 and 30 cms depth soil thermometers respectively. To support the thermometers at the correct inclinations, iron stands with sloping sides at 60° to the ground surface are provided. The soil thermometers are installed at a site in the observatory which is sufficiently away from obstructions and is free from water logging during the rainy season. Care should also be taken to remove the soil layer by layer and later replace the same in order, during installation of the soil thermometers.

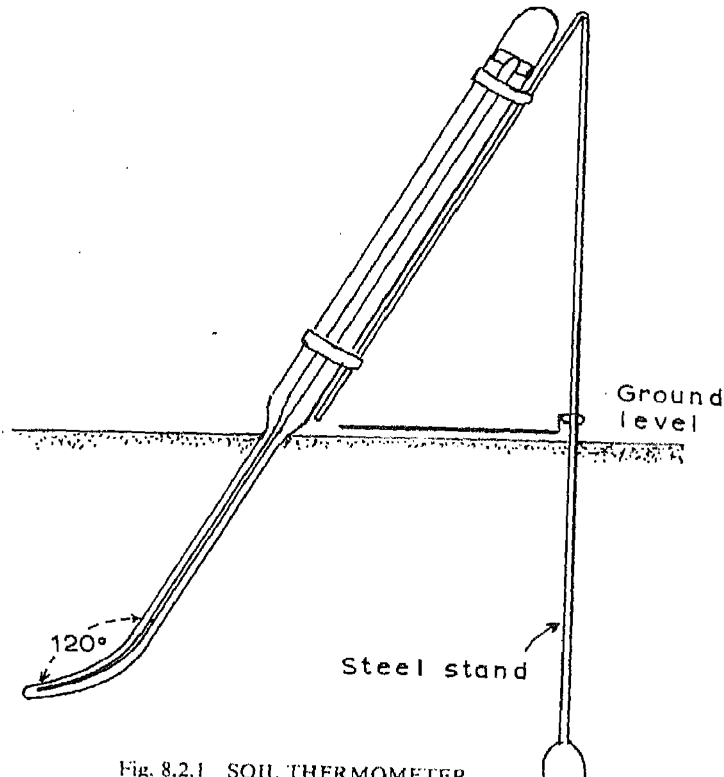

Fig. 8.2.1 SOIL THERMOMETER

The soil temperature should be read daily at 0700 hrs and 1400 hrs Local Mean Time (LMT) correct to 0.1°C, in the order 5, 15 and 30 cm depths.

8.3 Precautions :

— At the time of observations, sit sufficiently away from the soil

thermometer so that no shadow would be cast near the thermometer.

— Avoid parallax error while reading by keeping the line joining the eye of the observer and the top of the mercury column at right angles to the thermometer.

— If rain water gets collected in the soil thermometer plot, remove the same by digging drainage channels all around the plot.

8.4 Materials required :

i Soil thermometers for 5 cm, 15 cm and 30 cm depth.

ii. Iron stands for installing the thermometers.

8.5 Procedure :

— Install the thermometers with the help of iron stands as discussed in sub head 8.2.

— Read correct to 0.1°C soil temperatures at 0700 hrs and 1400 hrs Local Mean time (LMT) in the order of 5, 15 and 30 cm depths.

8.6 Observations :

The pupil should record the following

— Soil temperatures at 5, 15 and 30 cm depths in the morning at 0700 hrs and 1400 hrs LMT.

8.7 Expected behavioural outcomes :

The pupil will be able to :

— explain the significance of soil temperature in agriculture;

— measure the soil temperature at different depths.

Grade

The teacher should evaluate the pupil for the above abilities.

8.8 Questions :

i. Why is soil temperature important during crop germination and extraction of nutrients and water by plants?

ii. How are soil thermometers installed?

9 Activity Unit

ESTIMATION OF EVAPOTRANSPIRATION

9.1 Instructional objectives :

The pupil should be able to :

- — explain the meaning of evapotranspiration;
- — estimate crop evapotranspiration from Pan evaporation values at different stages of crop growth;
- — determine total water use of the crop for the whole crop season.

9.2 Relevant information :

What is evapotranspiration? How it depends on crop, soil and atmospheric factors?

The evapotranspiration is the combined loss of water from the cropped field due to transpiration from crops and evaporation from the intervening soil surface. At the time of germination, the evaporation component predominates. As the crop grows in height and ground is shaded, evaporation from soil decreases and transpiration rises progressively with increase in leaf area till the whole surface is effectively covered by the crop. Transpiration is insensitive to further leaf development and is maintained at a high level when plant is actively growing. This period varies with the growth characteristics of the particular crop. It decreases as the plant matures. Another important effect of crop is that as the roots develop, the crop has access to increasing volume of soil water. The most important factor however, is the available soil moisture status. As the soil moisture decreases progressively from the field capacity, the evapotranspiration also decreases and rapidly so after certain available moisture level. In addition to these crop and soil factors, evapotranspiration is also dependent on the atmospheric factors such

as saturation vapour pressure deficit, wind speed and net radiation.

— *What is potential evapotranspiration ?*

As explained above, computation of evapotranspiration, is complicated in view of it being dependent on fluctuating plant physiological, soil physical and atmospheric parameters. In order to simplify the same, the concept of potential evapotranspiration was evolved by Thornthwaite and Penman. Potential evapotranspiration is defined as the water loss that will occur if there is no deficiency of water in the soil for the use of vegetation at any time of its growth.

— *What are the common methods of determining the evapotranspiration?*

The evapotranspiration of the crop is measured by means of weighing type of lysimeters. It can also be estimated by the following climatological methods:

i. Determination of potential evapotranspiration by Penman's method by assuming an albedo value appropriate to the crop (viz. the percentage of solar radiation reflected by the crop).
ii. Climatological water balance approach using appropriate patterns of soil moisture depletion.
iii. Blaney-criddle method.
iv. Pan evaporation method.

Of the above four methods, the last method is comparatively easy to handle and makes use of the pan evaporation values recorded at the actual crop field itself. Hence this method is useful and the same has been elaborated below.

— *How is evapotranspiration determined ?*

Evapotranspiration of crop (Et) is obtained from Class A Pan evaporation (E) values (See Activity Unit-6) by multiplying the same by the crop coefficient (Kc) as per the following formula:

$$Et = Kc.E.$$

Where : Et and E are measured in mm per day.

The crop coefficients depend on the foliage characteristics of the crop, stage of growth, climate and geographical location. A few crop coefficient values in respect of some important crops are given in Table 9.2.1. The following example would clarify the calculation of evapotranspiration by this method.

Table 9.2.1. Crop factors to determine evapotranspiration from class A pan evaporation data

Stage of crop growth (in % of crop growing season)	*Wheat*	*Sorghum*	*Maize*	*Cotton*	*Rice*	*Groundnut*
1 10	0.18	0.44	0.43	0.22	1.02	0.31
10 20	0.34	0.48	0.55	0.24	1.05	0.36
20 30	0.57	0.53	0.74	0.40	1.09	0.50
30 40	0.80	0.60	0.95	0.78	1.13	0.69
40 - 50	0.90	0.71	1.07	1.02	1.18	0.84
50 - 60	0.90	0.91	1.10	1.08	1.21	0.93
60 - 70	0.86	1.06	1.09	1.04	1.22	0.95
70 80	0.80	1.08	1.04	0.93	1.19	0.90
80 90	0.71	0.98	0.95	0.73	1.10	0.79
90 100	0.58	0.81	0.80	0.51	0.95	0.64

(Adapted from the report by Water Management Division, Department of Agriculture and Irrigation, Government of India, 1971.)

— *Calculation of evapotranspiration of wheat :*

The total growing season of 120 days is divided into 10 equal parts of 12 days each. Let us assume the following values are the mean daily pan evaporation (E) for the ten sub-periods. The crop coefficients (Kc) are taken from Table 9.2.1. For these sub-periods, evapotranspiration calculated by E×Kc for each of the sub-periods are as follows. The total water use is obtained by adding Et values for all the sub-periods which are computed by multiplying by mean Et value and the number of days in the sub-period viz. 12 days.

Sub period	*Mean E (mm/day)*	*Kc*	*Mean Et (mm/day)*	*Total Et for Sub-period (mm/12 days)*
1	3.1	0.18	0.56	6.72
2	2.9	0.34	0.98	11.76
3	2.8	0.57	1.60	19.20
4	2.7	0.80	2.16	25.92
5	2.6	0.90	2.34	28.08
6	2.8	0.90	2.52	30.24
7	3.0	0.86	2.58	30.96
8	3.2	0.80	2.56	30.72
9	3.6	0.71	2.56	30.72
10	4.0	0.58	2.32	27.84
Total water use (mm)				242.16

9.3 Precautions :

- Use proper crop coefficient applicable to the crop.
- Care should be taken while calculating the mean evaporation for different stages of the crop growing season by selecting and appropriate crop coefficients for those stages.

9.4 Materials required :

i. Daily Pan Evaporation values from Activity Unit-6.
ii. Crop coefficients for the different stages of the growing season of the crop concerned.

9.5 Procedure :

- Divide the total growing season of the crop into ten equal periods.
- Compute mean pan evaporation (E) (in mm/day) by averaging daily values for the period.
- Pick up the appropriate crop coefficient (Kc) from Table 9.2.1.
- Calculate evapotranspiration of the crop (Et) for each of the ten periods by multiplying pan evaporation value and crop coefficient (i.e. by the formula $Et = Kc.E$).
- Compute total water use of the crop during the whole growing season by adding all the Et values of the ten periods.

9.6 Observations and Calculations :

The pupil should record daily pan evaporation and estimate the following :

- Daily evapotranspiration using the Crop coefficients appropriate to the different crop growth stages.
- Total water use of the crop.

The pupil should use the observations and follow the steps given in the procedure above for the purposes of calculating evapotranspiration and computing total water use of the crop.

9.7 Expected behavioural outcomes :

The pupil will be able to :

Grade

- explain the concept of evapotranspiration and various methods of determining the same;
- estimate crop evapotranspiration at different

stages of the growing season;
— compute total crop water use for the whole growing season.

The teacher should evaluate the pupil for the above abilities.

9.8 Questions :

i. What are the various crop, soil and atmospheric factors that are related to evapotranspiration?

ii. What are the four standard methods of determining evapotranspiration?

iii. Compute evapotranspiration for the following data :

Mean pan evaporation	*Crop coefficient*
a) 5.6 mm/day	0.94
b) 7.1 mm/day	0.81
c) 3.5 mm/day	1.16

iv. How is the crop water use for the whole growing season determined?

v. Given the following mean pan evaporation values during the successive 10 days period of the crop growing season of Maize (100 days crop); calculate the total water use of the crop.

10 day period	*Mean Pan evaporation mm/day*
1	5.4
2	6.9
3	7.1
4	5.5
5	4.8
6	4.3
7	5.9
8	3.2
9	6.0
10	5.7

Appendix-I

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